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DEVELOPMENT AND RESULTS IN PHYSICS IN HUNGARY SINCE THE LIBERATION

A Magyar Tudomány Tíz Éve  
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Zoltan Gyulai

## I

Prior to Liberation research in physics in Hungary was limited to a few university institutes and to the research laboratory of the Ujpest Incandescent Lamp Factory. In the spirit of the old university research was guided by the individual preference of the directors and the physical limitations of the available equipment, and while purposeful work was carried on at the research laboratory of the Ujpest Incandescent Lamp Factory it had primarily industrial aims. The financing of experimental physics research was a relatively heavy burden to the universities, but the situation was somewhat better at the research laboratory of the Ujpest Incandescent Lamp Factory. Experimental research was conducted at approximately 6 university institutes.

Research in theoretical physics also was tied to the theoretical physics chairs of the universities. Research in experimental physics was conducted at approximately 3 locations.

Karoly Novobatzky conducted research in isolation at Pestujhely. Only a few people knew that he was one of the most outstanding proponents of the theory of relativity.

Reorganization began very slowly following Liberation, but approximately 4 years later the organizational skeleton of research in physics in Hungary had been completed. The organization of physics research originally was planned on a grand scale. The supreme and imposing expression of this conception was embodied by the Central Physical Research Institute (KFKI), under the direct supervision of the Academy of Sciences. (This book contains a separate account of the KFKI.)

The development of the chairs of physics of the universities also was begun on a grand scale. New university chairs were founded. Although the principal consideration in the organization of these academic chairs was adequate execution of the increased educational tasks of the universities, the aspect of physical research also was given great consideration.

As a result of the new organizational measures the number of physics chairs increased to twice, and the number of teachers increased to 3 times the old level. Entirely new types of physics chairs also were founded. Among the latter are the 3 medical physics institutes of the medical schools.

Another important qualitative factor in scientific work is the equipmentation of the institutes. The extremely rapid development of this field also can hardly be properly evaluated. During the 5 years immediately following World War II, and even in the 2 or 3 years after that neither the financial nor trade possibilities existed for adequate equipmentation of this field of science. After Liberation both the Ministry of Education and the Academy of Sciences were very much concerned with the problem of the equipmentation of the institutes. The institutional expression of the latter is the fact that the university institutes of physics receive aid from the MTA Magyar Tudományos

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Akademia -- Hungarian Academy of Sciences<sup>7</sup> in the pursuance of their particular goals. As a result, the material resources of the university institutes of physics for training and research purposes far exceeds that of the past.

One of the most outstanding results of the new cultural program in the field of technology is the fact that the Hungarian experimental research institute could not function without adequate technical establishments, and without mechanical, glass technical, electro-mechanical, and joining shops. This aspect must be emphasized because this fact was not recognized by the old directorate, and wherever such shops were set up it was possible only through great personal efforts. It must be admitted that in earlier times even the professors were not always aware of the importance of such organizations. Because of the individualistic isolation of earlier times the banding together of several academic chairs to create and share at least one adequate installation was not even attempted. At present this situation has been completely changed and although every institution still does not have an adequate number of suitably trained research personnel at least the field of physics research is on the right track for desirable development along this line.

Considerable developmental progress has been made through the founding of new academic chairs of physics accompanying the completion of new teacher training colleges. Although these academic chairs are only in the first stages of development they constitute new centers for the development of the field of research.

Although the overall picture of the development of the university and college institutes of physics is excellent there is one sore point, namely the problem of the premises of the institutes. Despite the fact that investments were made in this field also, the space occupied by the institutes was not increased in proportion to the development of the organizational framework of the institutions. Although the excellent institutes of the KFKI are still being completed they already have produced excellent results which, however, because of the remoteness of the institutes from the research center, have not received adequate publicity. The special demands which are necessary for convenient instruction under the modern forms of education still have not been met. The elimination of this very serious lack is a very important task of the immediate future.

The training of specialized physicists which has been instituted since Liberation is providing specialists for increased and enlarged technical institutes. It must be borne in mind that previously only professors versed in both mathematics and physics were trained in Hungary. The academic and research personnel of the institutes came from the ranks of such trainees. The number of such auxiliary personnel, however, was very small. For example, 20 years ago some institutes had only 2 or 3 assistant professors. Even at that time this organizational set up was not adequate to fully occupy ambitious and brilliant technical students trained in mathematics and physics.

All this has been substantially changed with the present system of training physics specialists in the universities, as well as training professors of mathematics and physics. Although this training method still has not been completely perfected it already has produced significant results. The development of this program for training physics specialists is being furthered by the recently introduced and presently stabilized method of aspirant training which, although extending over all branches of learning, is particularly promising in the field of physics.

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The Eotvos Lorand Physics Society plays an important role in cultural propagation and training outside the schools, and in the broad exchange of knowledge. The old Eotvos Lorand Mathematics and Physics Society has now divided into 2 separate institutions. The mathematics section has been reorganized as the Bolyai Mathematics Society, and the physics portion has expanded and continues to function as the Eotvos Lorand Physics Society. Both societies are under the supreme supervision of the Academy of Sciences. In addition to its weekly evening meetings, the Eotvos Lorand Physics Society holds an annual itinerant conference which lasts several days. The "Hungarian Doctors' and Natural Science Investigators' Itinerant Conference" has held national conferences for the discussion of the achievements in the fields of natural and medical sciences every 4 years since 1846. However, the development of science and this old and very important institution have been inadequate to this modern demand since the turn of the century. Independent itinerant conferences have been held in individual broad fields of science, such as the biological society, the physiological society, etc. The leading officials who should have been concerned, failed to provide an adequate organization for those branches of science which comprised fewer institutes and personnel than the field of physics which would be adequate for the institutional activity and social effect of these sciences. The present activity of the Eotvos Lorand Physics Society should be evaluated in the light of the latter factors, also.

Although the details still must be improved and further developed, the essential framework necessary for successful work already has been established. That this framework is adequate is borne out by the fact that despite the great work consumed by the organization and equipmentation of this framework significant results have been achieved during the 10 years which have elapsed since the liberation, and especially during the past 5 years. A brief survey of these results is given below.

## II

The following results in the field of theoretical research may be mentioned.

### Theory of Relativity

Karoly Novobatzky was occupied with the problem of relativity throughout his entire lifetime and following Liberation he gathered a school of followers. He was the first to demonstrate that the usual method used for the determination of the square component of the relativistic square power  $\Phi$  does not always give a good result because the assumption used in this derivation, that the squaring operation is equal to zero, does not always apply. This method is successful for electromagnetic forces, but not for conservative forces taken in a relativistic sense. In the latter case the squaring operation is equal to the change in potential  $-dV$ . Novobatzky showed that in conservative fields of force the mass equivalent value of the local potential energy of a particle at its location is additive to the mass at rest, and as a result the resting mass of a particle changes from place to place.

Karoly Novobatzky also worked on the problem of the forces acting on dielectrics at rest and in motion, which at that time had not yet been solved. In this work Novobatzky used the method which has been very successful in the field of the theory of relativity in developing the Lagrange function from which the now known spatial equations and

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spatial energy expression of the electrodynamics of dielectrics is derived. From this the energy-impulse tensor which determines the force acting on isotropic dielectrics through the electromagnetic field could be readily derived.

This result confirmed the validity of the tensor derived by Abraham.

The same problem was investigated by another approach by G. Gyorgyi and Gy. Marx, and they found the expression of the field forces acting on the dipole which is formed in the dielectric to be equal to the expression developed by Abraham.

Gy. Marx generalized the isotropic dielectric results of K. Novobatzky in relation to anisotropic substances.

The determination of the effect of an electromagnetic field on a permanent magnet has been a long debated problem. Gyorgy Marx applied the method used for determination of the energy-impulse tensor in the generalized theory of relativity in the solution of this problem, and showed that the divergence of the energy-impulse tensor derived from the Lagrange function gives the laws governing the forces acting on magnets at rest and in motion.

In his investigation of the same problem Janos Horvath obtained more general results. Using the method of Weyl, Horvath derived the equation of the motion of dipoles, and his results also account for the back-action of the electromagnetic radiation generated by the accelerating magnetic dipole.

Gyorgy Marx developed a method for determination of the energy-impulse tensor of fields of force which are described by higher order field equations which are in interaction with the environment, based on the special theory of relativity of Euclidian geometry.

The proportionality of heavy and inactive masses is one of the basic principles of physics. Gy. Marx poses the question of the type of gravitational field generated by masses in motion. Many universities throughout the world have been occupied with the determination of the forces of inactive bodies. Marx shows that a similar phenomenon occurs in electrodynamics, in that a rotating body generates a magnetic field as a result of interaction with the gravitational field of the masses adjacent to it. This indicates a close connection between gravitational and electromagnetic forces.

Because it has not been possible to attribute sufficient physical properties to the fifth dimension, Karoly Novobatzky has continuously attempted to derive the fifth dimension from the theory of relativity. In the presentation on the occasion of his accepting his academy chair, Novobatzky described a unified theory of space which describes phenomena in terms of the space-time four dimensional geometry. The curvature of space is determined by gravitation. The geometric effect of an electromagnetic field is observable through the divergence between parallel vectors. The curve described by the parallel divergence of a velocity vector along its own line of direction serves as the course of a particle. This fact is illuminating with respect to electromagnetic effects, as well as to the effects of gravity.

Janos Horvath is basing his work along this line of theoretical research on the geometry of Finsler. In Finsler's space the force effects produced by an electromagnetic field have a favored direction. An invariant distance also may be treated in the terms of this space, which is



defined by a curvature tensor, which also gives information on gravitation.

In another report Janos Horvath discusses whether the geometric evaluation of an electromagnetic field is possible independent of gravitational effects. In his opinion this is possible.

Two works of Pal Selenyi must be mentioned in connection with the theory of relativity, which are basic questions of the development of the theory of relativity. Selenyi describes a simple experimental method for the comparison of heavy and inert masses. If the inert mass of a body floating on water were not equal to the inert mass of the displaced water the centrifugal force of the rotating earth would drive the floating body toward the poles or toward the equator. His other work is a further development of the rotating balance experiment used to demonstrate the Eotvos-effect. Instead of a rotating balance he uses a pole mounted horizontally in a north-south direction which is placed in oscillation through torsion. Because of the Eotvos-effect the pole will have vertical displacements, which can be accentuated through utilization of resonance.

In his academic chair acceptance speech Lajos Janossy contributed to the clarification of the basic principles of the theory of relativity. His concept may be considered a further development of the Lorentz contraction hypothesis.

Tibor Matrai also has done work in the field of relativistic kinematics, and he has achieved significant results. Matrai developed certain hypotheses with respect to the rigid movement of mass points which yield 6 degrees of freedom, in contrast to the work of Max Born.

Fenyves demonstrated that the classical investigations of Gyula Farkas with respect to the differential theories of mechanics are completely equivalent to the conventional method of approach, but in a different sense. According to this view the theory of virtual displacement is not a displacement of infinitely great velocity, but is a Galilean transformation of the possible displacements. Furthermore, the theory of virtual displacement is dispensable. He indicates in his work that in this manner the relativistic generalization of differential theories is possible (Lorentz transformation instead of Galileo transformation), which previously was prohibited by the infinitely great velocity postulated for the virtual displacement.

In the field of domestic literature on the theory of relativity, the university text book by Novobatzky must be mentioned, which is a notable work even on an international scale.

During the past year Geza Szamosi and Gyorgy Marx have been working in the field of relativistic dynamics and their results are of interest to the field of nuclear physics, also.

Tibor Neugebauer has investigated an interesting problem in connection with the existence of magnetic poles. However, the most outstanding results of Hungarian researchers have been related to the discussion of the energy and impulse relationships of electromagnetic radiation passing through insulators, in terms of spatial theory methods. Under the leadership of Karoly Novobatzky these researchers have systematically developed this problem which has been a moot question for half a century, and they demonstrated for the first time a method by which all phenomena in this field may be evaluated on the basis of a unified theory. Gyorgy Marx and Geza Gyorgyi investigated the classical problems, taking the work of Karoly Novobatzky as a starting point. Karoly Nagy developed the

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quantum theory of photons passing through an insulator in his candidate's thesis. In 1951 Gyorgy Marx was awarded the Rezső Schmidt prize by the Eötvös Loránd Physics Society for his work in physics.

The residual theories of physics, the law of the residuum of energy impulse and impulse-momentum, lend themselves very well and in a unified sense to discussion under the terms of the theory of relativity. The Hungarian physicists who have worked on problems along this line include Karoly Novobatzky, Gyorgy Marx and Pal Roman.

#### Quantum Theory

The quantum theory is beyond doubt one of the most important fields of modern physics. At the turn of the century this branch of science revolutionized the concept of the structure of matter, and since the 1920's the general methods developed in this field have placed a powerful tool in the hands of the physicists. Despite all the advances achieved, however, there are still 2 open questions in the forefront of research. First of all, it cannot be said that the quantum theory is a closed chapter with respect to logic and philosophy. Secondly, the experiments aimed at description of the behavior of elementary particles under the quantum theory, or the general quantum theory of elementary particles, still have not produced noteworthy results.

Hungarian physicists have done significant work in both fields during the past 10 years. Hungarian researchers have done varied and extensive work primarily with respect to the theoretical problems of the quantum theory and in the evaluation of theoretical problems. Academician Karoly Novobatzky was awarded the Kossuth Prize for his results achieved in this field. Academician Lajos Janossy worked on similar problems, but with a different approach, as did Imre Fenyves, who was concerned primarily with the possibility of hidden parameters. It is mentioned here that Lajos Janossy also investigated the philosophical problems related to this subject. In his investigation of theoretical problems, Imre Fenyves also obtained important practical conclusions.

The quantum theory of fields of force is a well developed branch of physics research. Gyorgy Marx, Geza Szamosi and Pal Roman have done work in this field in connection with the spin of elementary particles. The work of Geza Szamosi has dealt with the problems of higher order fields.

An especially large number of researchers have done work on the problem of quantum electrodynamics. Academician Karoly Novobatzky had commenced work in this field in Hungary as early as the 1930's. Pal Roman recently has been occupied with formulation of the expression of an electromagnetic field in terms of quantum theory. Frigyes Karolyhazi has published a discussion of the complex problems of the interference of photons by quantum electrodynamics methods. Peter Farago and Gyorgy Marx have done work on a possible method of experimental control of quantum electrodynamics, utilizing the quantum energy transferral of cavity resonators. The work of Judit Nemeth is along the same lines.

Two research projects of Gyorgy Marx in the field of quantum field theory have dealt with the description of the mutual interaction of elementary particles. Pal Roman is doing work on the polarization of a vacuum. Two projects of Aladar Komjathy deal with certain peculiarities of photon and de Broglie waves.



### Cosmic Radiation and Nuclear Physics Theory

Research on the theory of cosmic rays and nuclear phenomena began in Hungary after the war.

L. Janossy was the first to begin work on the theory of cosmic radiation. A large part of the work of Janossy relates to the cascade theory. The most important recent work developed by Janossy is the G equation, which has been cited frequently in the literature. In his later work, Janossy generalized the G equation. Several derivations are possible with the generalized theory which could be obtained from the original theory only through long and arduous calculations. The wide range of the work of Janossy also encompasses the further development of the mathematical apparatus of the theory of cosmic radiation in many different aspects. Thus it may be hoped that Hungary may achieve renown in this field of physics, which has been little developed in Hungary in the past. One indication of such achievement is the fact that 4 of the works of Janossy have been or will be published in the journal of the academy of sciences of the Soviet Union. Janossy was awarded the Kossuth Prize in 1951 for his work in Physics. It should be mentioned also that Janossy increased the prestige of Hungarian research in cosmic radiation through the publication of his books (including his great monograph) which have also been published in England, the Soviet Union, Germany, and Italy.

While research in cosmic radiation gained impetus through the return of world-famous Hungarian scientists to Hungary, domestic research in theoretical nuclear physics gained its impetus from gradual development of original Hungarian research. Tibor Neugebauer was working on the magnetic momentum of atom nuclei in 1937. Significant results have been achieved in the field of nuclear physics in recent times.

Three works of Pal Gombas deal with the problems of the basic status of atom nuclei and determination of the cohesive energy of atom nuclei and the density of nuclear particles. It is worthy of note that only one empirical parameter is involved in the theory. The numerous works of Geza Szamosi and his associates deal with modern problems of the skin structure of atom nuclei and with other problems. (The work of Geza Szamosi along this line was awarded the Rezső Schmidt Prize in 1953 by the Eötvös Loránd Physics Society.) One of the works of Karoly Nagy also is along this line.

Hungarian researchers also have become interested in the problems of the induction-excited state of atom nuclei. A work of Gyorgy Marx deals with the dilation vibrations caused in atom nuclei by strong inductive-excitation. Geza Szamosi utilizes several new results in the field of nuclear forces in the determination of the energy density of the induction-excited state of atom nuclei. A work of Gyorgy Marx and Geza Szamosi deals with the role of atomic nucleus surface tension in the induction-excitation state of the nucleus.

The third field in which Hungarian physicists have done extensive work is that of the problems of nuclear forces. Utilizing relativity theory methods Gy. Marx and Geza Szamosi showed that the existence of repulsive forces between the active parts of atom nuclei can be derived from very recent experiments. A work of Tibor Neugebauer deals with the problem of the distance function of nuclear forces. Although not strictly within the field of nuclear forces a work of Gyorgy Marx pertaining to nuclear forces may be mentioned here, in which Marx sets up a hypothesis for the so-called residual fermion charge.

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The Statistical Atomic Theory, the Wave-Mechanics Approach Methods, and Their Applications

A world-famous Hungarian school of thought has been established in this branch of modern physics (which is of great practical importance), due to the work of Pal Gombas. The results achieved by Gombas are the most important in this field, both qualitatively and quantitatively.

The only monograph in this field was written by Pal Gombas, has appeared in German and Russian language editions, and has received world-wide recognition. This work reviews all theoretical results and practical applications used since 1949. Gombas also is the author of the description of this field in the new edition of Handbuch der Physik [Handbook of Physics], which includes the developments in this field in Hungary since 1949.

During the past 10 years Hungarian researchers have been active in the following fields.

The statistical expression of the Pauli principle is of basic importance to the statistical atomic theory because the mutual orthogonal expression of the functions of individual electrons is not possible under the terms of the latter theory. Gombas long ago showed that the Pauli principle may be taken into consideration under the statistical atomic theory by the utilization of a repulsion potential, and he also derived a method for the analytical expression of this potential. Gombas recently succeeded in correcting the repulsion potential, as a result of which the numerical values of the d-valence electrons have been considerably improved. Utilizing these corrections Gombas has constructed a statistical model in which the electrons may be grouped according to their auxiliary quantum numbers, and the density of s-electrons at  $r = 0$  no longer diverges (which is contrary to the Hellmann grouping). Fenyés showed that the variation problems which give rise to the Hartree-Fock equations may be solved by the use of nonorthogonal functions, in which the Hartree-Fock equations are modified by the appearance of a repulsion potential. The null-expression of the repulsion potential derived in this way is suitable for use with the Gombas expression described above. Fenyés also has succeeded in grouping the electrons of the statistical atomic model according to auxiliary quantum numbers and in eliminating the divergence of the Hellmann grouping, but his method is more unwieldy than the new method developed by Gombas.

Researchers in the field of statistical atomic theory long have been at a loss to explain the excessively large value of the so-called (Weizsacker) inhomogenation correction of kinetic energy. The location and correction of this error was desirable because the electron density of the statistical model exhibits the same exponential decrease with the use of the inhomogenation correction as does the electron density calculated according to the wave mechanics theory. Gombas also successfully solved this difficulty, through the introduction of his "kinetic specific energy" concept. Gombas showed that the energy value derived through the use of the Weizsacker correction is too large because the "kinetic specific energy" appears in both the Fermi zero-point energy and in the inhomogenation member, and thus appears twice in the calculation. Gombas determined the expression of the kinetic specific energy and through the use of this value developed a statistical model of the energy and electron density of which are in excellent agreement with the wave mechanics values. Pauncz also has done work on the problem of the accuracy of the Fermi scheme of kinetic energy. He found that the zero-point energy calculated according to the quantum mechanical box-model is much larger than that derived by the Fermi method. This indicates that the impulse



of the electrons of a Fermi gas can be equal to zero (which is contrary to the present hypothesis).

The connection between the wave-mechanics and statistical atomic theories has not only theoretical interest, but is an important problem from the point of view of the further development of the statistical model, as well. Fenyés has further developed the results of Dirac and Brillouin in this field, and he has greatly simplified the expression of their ideas and rendered them more readily verifiable. His method consists essentially of solution of the "self-consistent field" equations with the use of the W. K. B. method, which leads to the unified wave-mechanical establishment of all forms of the statistical model. Gaspar showed that the electrostatic potential, which appears as a universal function in the statistical atomic theory, exists with very good approximation in both the Hartree and the Hartree-Fock methods. When this is taken into account the statistical model can be of very great aid to the wave-mechanical methods. Gombas recently demonstrated that the basic statistical equations pertaining to the electron density of the statistical model are very similar to the wave-mechanical equations of the multiple-body problem. Gombas thereby demonstrated the close connection of the statistical and wave-mechanical theories from the opposite approach. Fenyés elaborated the analogy discovered by Gombas through the addition of several new viewpoints which further strengthen the connection between the two theories, and indicates a possibility for the correction of the electron density of the statistical model which also gives information on the skin structure.

In a joint work Gombas and Gaspar utilized the Umeda solutions of the Thomas-Fermi-Dirac equation, which take account of the unsatisfactory Brillouin boundary surfaces, together with a perturbation method for the derivation of solutions pertaining to the more exact Jensen boundary hypotheses.

Hungarian researchers have originated several important uses of the statistical atomic model. Konya determined the profile of the Compton zone through the utilization of impulse distribution derived from statistical density values. The theory of metals derived by Gombas on the basis of statistical atomic theory is an important development, which is discussed in the section on the theory of solids. Investigations in the field of statistical nuclear theory also are discussed separately under the heading of theoretical nuclear physics.

Many Hungarian researchers also have done work on other methods of theoretical expression and certain special applications of quantum mechanics. The major work in this field, also, is the monograph of Gombas, which has appeared in German and Russian language editions, as well (the second edition already has been released).

The work of Gombas and Gaspar is very noteworthy, which gives the theoretical justification of the semi-empirical Slater self-consistent function. An analytical method developed by Gombas and Gaspar also may be mentioned here, which is used in the determination of the self-consistent functions of the atomic electron. This work utilizes the results of Gaspar (mentioned above), according to which the reduced effective nuclear charge obtained by the "self-consistent field" method, expressed in appropriate units, is a universal function independent of serial number.

In a study of the problem of the divergency of the W. K. B. method Imre Fenyés established that the series derivation method used in the W. K. B. method does not exist. He also showed that an existing series derivation always may be applied (according to the  $\pi$  effects). The

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investigations of Fenyés on phase quantum derivations and the wave mechanics basis of mathematical methods based on classical foundations also are relevant to this field of research.

Some individual special applications which may be mentioned are the following: the calculations of Gaspar pertaining to the dispersion of x-rays. Janos Horvath performed again the usual calculations pertaining to the HCl molecule, utilizing the recently developed more accurate density tables. Geza Freud discussed a method for the mathematical treatment of the H<sub>2</sub> molecule, and Zsolt Naray discussed a method for the mathematical treatment of the HCl and HF molecules. Berenc and Gaspar developed new methods for the accurate determination of the binding of the H<sub>2</sub> molecule. Gaspar and Konya determined the constants of the HI molecule on the basis of the correlation-supplemented statistical model.

A work by Gaspar adds several qualitative determinations to the statistical atomic theory, and 2 works by J. Horvath add to the variation method.

### Molecular Theory

Several Hungarian researchers have done significant work on the molecular theory. Agoston Budo has investigated the dielectric relaxation of polarized molecules and extends the theory to ellipsoid shapes in the case in which polar groups can rotate freely within the molecule, and when such rotation is inhibited. Because the structure of molecules varies greatly, Budo devoted 2 works to the investigation of characteristic special molecular structure. His results are in good agreement with experimental data. In his next work Budo will treat the effect of environment on the polarization of molecules through complicated mathematical calculations. Because the mathematical methods used in the molecular theory are very specialized, Budo treats these methods in a unified manner in a separate work. Pal Kovesdi, a study of Budo, generalized the Debye-Ramm theory for ellipsoid shapes for use with high frequency and for the performance of dielectric investigations.

The works of Istvan Kovacs and Agoston Budo which further develop the theory of zonal perturbation in spectroscopic photographs and the methods for determination of the molecular term constants which cause perturbation also fall within the field of molecular theory. In a joint work by these 2 researchers they investigated the problem of the perturbation between 2 discrete and one continuous term series through utilization of quantum electrodynamic data, which they published as an explanation of the phenomenon known as accidental predissociation. In another work they investigated the reciprocal effect of spin-path on the structure of certain multiple states. In another work they derived explicit formulas for the transitory state term values between the Hund-type b and d linkages, and for the distribution of intensity in the zonal branches and for the Zeemann decomposition of the terms. They successfully applied their results to one term complex of the He<sub>2</sub> molecule.

In another work Budo and Kovacs discuss the problem of perturbation in the zones of spectrographic photographs from a unified viewpoint, taking into consideration the reciprocal effect of electron path and spin momentum. Through this method they succeeded in presenting for the first time in the literature, an explanation of the perturbation between the various multiple terms of the zones of the spectroscopic photographs of molecules. For the benefit of nonspecialists in this field, they have published an account of the structure of molecular color photographs under the title Molekulaszinkepek [Spectrographic Photographs of Molecules].

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Istvan Kovacs and the Swedish researcher Albin Lagerquist established the oscillatory and rotational term system of electron states caused by perturbation solely on the basis of perturbation data of the spectrum lines of barium oxide. By way of further development of these methods I. Kovacs gives a general discussion of the previously developed methods for determination of the constants of molecular terms which cause perturbation. In another work he describes the newer methods for determination of the molecular term constants which participate in the transition.

Budo and Kovacs presented an explanation of the anomalous behavior of the  $4\sigma$  term, which is the only term of the spectrograph of the  $O_3^+$  molecule which has been subjected to detailed experimental study. Their results agree with the measurement data. The work of Budo and Kovacs was awarded the Kossuth Prize in 1951.

The spectroscopic investigation of molecules began anew in Hungary after the Liberation. Kovacs and Budo, Iren Deezsi, Edit Koczka and Tibor Matrai reported the discovery of several rotational analytical zones within the blue zone system of strontium oxide. On the basis of these discoveries they solved the problem which has been long disputed in the literature, viz., that the lower electron state of the blue zone system is common with the lower state of the ultra red zone system.

Tibor Neugebauer is occupied with the calculation of the ellipsoid of polarization of the hydrogen molecule. He shows that the ellipsoid consists of the superposition of 2 phenomena, and the reason why researchers have been unable to confirm the observed data in the past is that they had taken only one of these phenomena into consideration. Another work by Tibor Neugebauer deals with the role of polarization phenomena which appear in crystal grid systems play in the determination of the type of grid system of the crystal, in the appearance of semileading characteristics, and in the problem of the transition between the 2 types of binding. Janos Horvath did work on the polarization of the HCl molecule, and some of his results have helped supplement the method of Gombas and Neugebauer. In a later work he further refined the method used, in that he treats the polarization of individual, closed electron shells. In 2 later works J. Horvath further improved his results after improvement of his mathematical methods and his physical line of reasoning. In 2 of his works Tibor Neugebauer evaluates biological processes with the help of the van der Waals reciprocal effect. In one of these works he discusses the fact that through van der Waals forces, polypeptide chains which have been straightened out can bind amino acids. In his next work he applies the van der Waals reciprocal effect to the aromatic hydrocarbons.

Rezső Pauncz has been working on the optical characteristics of molecules, on the basis of the Pauling method. His results state that theoretical computations can agree with experimental data only if the calculations include ionic, as well as homeopolar functions. In another work Pauncz attempts to explain the spectrographic picture of condensed aromatic molecules on the basis of a quantum mechanical model. R. Pauncz and Ferenc Berencz investigated the magnetic properties of molecules. They studied the connection between diamagnetic anisotropy and the shape of the molecule in aromatic compounds. Their results are in good agreement with experimental data. Pauncz and Berencz also have computed the diamagnetic anisotropy of a very complicated condensed aromatic compound, and are investigating the effectiveness of the mathematical methods for the treatment of this problem.

Janos Horvath has been working on the binding relationships of molecules, applying the method of T. Neugebauer in the case of the ammonium ion. In another work, Horvath reconstructs the ammonium ion utilizing the method of Pal Gombas in the mathematical calculation, and he calculates

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the several Raman frequencies of the molecular ion. In another work he generalizes his earlier results to include the case in which the central core of the molecule is Si. Zsolt Naray has perfected the mathematical method for the calculation of the binding energy of molecules and of molecular constants. R. Pauncz and Ferenc Berencz utilized the method of the linear combination of atomic paths in determining the sequence of binding strength for individual bindings of aromatic compounds. In a more recent work they investigated changes in physical and chemical properties through the addition of benzene rings. Rezső Pauncz investigated the efficiency of the Moffitt method, and he states several principles for the proper selection of the wave function. In one work, Ferenc Berencz improved the molecular path method, and in another work he studied the Fourier-series method as applied to specific cases.

#### Thermodynamics and Statistical Mechanics

Imre Fenyes has published several works in the field of thermodynamics. Fenyes has been concerned with the axiomatic foundation of thermodynamics. He considers the thermodynamic system to be a mechanical system with several involuntarily imposed conditions. As Helmholtz had indicated earlier, this is possible because the thermodynamic concepts may be considered as the average values of mechanical properties of the molecules. Thus it is not at all surprising that the classical formalization is applicable to the mechanical averages. Fenyes uses a system with 2 degrees of freedom. He considers the Hamilton function to be internal energy and the Lagrange function to be free energy, and treats the irreversible mechanical theory through this formalization. In another work Fenyes deals with the quantitative characterization of irreversible thermodynamic processes. Fenyes has devoted several works to the axiomatic foundation of thermodynamics, as did Gyula Farkas, who performed experiments along this line as early as 50 years ago.

In the field of statistical mechanics Kalman Szell has been occupied with the Fermi statistical method, as applied to the degenerate stage of an ideal gas. In another work he investigated the variation in energy of single-atomic gases according to the statistics of Bose and Fermi. Szell also intends to extend his calculations to the variation in rotational energy of multiple-atomic gases.

In 2 joint works Jenő Egervary and Pal Turan have shown that contrary to the false notion that because of the large number of particles in gases the mechanical theory cannot be applied, with the consideration of certain conditions the density of the gas may be evaluated. In the end result, this means that the deterministic and statistical methods of approach can be made to agree. Fenyes has shown that the indeterminate relationship discovered by Furth in the theory of diffusion is applicable in a much generalized form to every stochastic process. Along this same line he attempts to derive the equation of diffusion dynamics.

#### The Theory of Solids

The research which has been conducted on the theory of solid bodies since Liberation may be divided into 2 groups: 1. investigations based on the statistical atomic model and 2. other quantum mechanical investigations. Pal Gombas utilized the metal theory which was developed even before Liberation, supplemented with a potential which includes the modified Pauli principle, for the calculation of the more important constants of alkaline and earth-alkaline metals, and extended the method to the noble methods, as well.

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This theory was further expanded to include theoretical determination of the status equation of metals, and the calculations of the pressure-compressibility curve of alkaline and earth-alkaline metals for higher pressure values.

Albert Konya calculated the Gruneisen constants of alkaline and earth-alkaline metals on the basis of the theory of metals derived by Gombas.

Rezzo Gaspar extended the calculations to metals with many valence electrons, primarily aluminum.

Tibor Hoffmann performed calculations on the RbI crystal, which also were based on the statistical atomic model.

Among other calculations based on the quantum mechanics method the so-called quantum chemical method should be mentioned, in which the quantum chemical methods were applied to a crystal, taken as a gigantic molecule. Using this method, Tibor Hoffmann and Albert Konya performed calculations on a crystal composed of single-dimensional uniform atoms, and Tibor Hoffmann later performed calculations on a crystal composed of two-, and three-dimensional uniform atoms. Hoffmann later extended the investigations to solid bodies consisting of different components (alloys), in the case of single-, two-, and three-dimensional cases. He later utilized this theory in the explanation of surface phenomena appearing in conjunction with certain problems of semiconductors, and of pollution phenomena. Hoffmann recently has made some progress in the application of this theory to pollution with a statistical distribution.

The following research was conducted in certain independent fields of the theory of solids. Tibor Neugebauer clarified certain problems of the Plotnikow dispersion theory. Pal Gombas and Tibor Hoffmann performed calculations on the mechanism of luminescence in the course of development of an industrial problem. Tibor Neugebauer investigated magnetic phenomena associated with hyperconductivity. Pal Gombas and Tibor Hoffmann performed calculations on the possibility of the contraction of organic chain molecules. Tibor Neugebauer investigated the reality of the null-point vibration of solid bodies, and also attempted to explain the magnetic behavior of the Earth. Geza Schay published a simple account of the thermal expansion of crystals on the basis of a classical model. The following experimental research was performed:

#### Electronics

Prior to Liberation research in the field of electronics was conducted only at the research laboratory of the Unified Incandescent Plant. The most intense research along this line following Liberation also was conducted at this laboratory. Theoretical research was concerned with the problem of thermal electron emission, which has great practical significance in the field of manufacture of electronic tubes. The second field of research along this line concerned the secondary emission of electrons and the electron multiplier, which is based on the latter phenomenon. Electron multipliers now are extensively used in laboratories. Peter Farago and L. Takacs employed the electron multiplier for investigation of the mechanism of secondary electron emission. Andras Dallos is developing a method for the measurement of the amplitude of impulses generated by the electron multiplier. J. Pocza utilized the electron multiplier for counting ultra violet photons. He also measured the quantum efficiency and, considering the fact that surface effects are involved, he found this value to be low, which is in agreement with the earlier photo-electric investigations. However, as Farago makes it plain, this is no hindrance to its practical applicability because the electron multiplier has a very

small side effect. Gyorgy Papp and Kalman Sasvari also use the electron multiplier for measurement of the intensity of x-rays, and in the analysis of crystal structure. P. Farago built and studied a type of electron multiplier with a large cathode surface. Gyorgy Szigeti and Elemer Nagy used the electron multiplier for the spectrographic registration of the luminescence of various types of fluorescent dust. P. Farago and J. Pocza have utilized the electron multiplier at the Szabadsag Mountain Observatory. The electron multiplier performs very well in this type of application. Farago and Pocza also have used the electron multiplier in coincidence equipment, which enables an analysis of  $10^{-7}$  to  $10^{-8}$  second with commercial grade tubes. J. P. Valko and Gy. Gergely have utilized the electron multiplier in research on luminescence.

Istvan Cornides has developed a homogenous energy ion source for mass spectrographic purposes.

Farago and his associates have developed a quantitative method for determination of the magnetic force of atomic nuclei by the radio frequency resonance absorption method.

Pal Selenyi has established the effect of mercury vapor on selenium rectifiers, and is investigating the phenomena caused by mechanical deformation of the rectifier plates. He also developed his electrographic method for the production of electron microscope photographs.

Selenyi reports on an important phenomenon of electronic physics in his work on the electric windmill, which ties in with his earlier investigations on the inert mass of electrons. Two of his works are devoted to the improvement of selenium rectifiers.

The appearance in 1954 of a monograph by P. Farago and J. Pocza entitled Elektronfizika [Electronic Physics] (Academy Press, 431 pages) must be mentioned as an important literary event.

Farago and Groma have done theoretical research in connection with problems of velocity-modulated generators, and which problems have been subjected to debate in the literature.

#### Radioactivity and Nuclear Physics

##### (a) Excitation of Atomic Nuclei

These investigations were begun under the initiative of Sandor Szalay prior to Liberation at the Physics Institute of the Debrecen University, and considerable progress has been made since Liberation. These investigations extend to several allied fields, also. The excitation state of light atom molecules is determined through measurement of the  $\gamma$  radiation. Eva Csongor bombarded magnesium and lithium with Po  $\alpha$  rays, and the same rays were used by M. Kovacs for bombarding Na atoms, and by Szalay-Csongor for bombarding Mg. Janos Nagy investigated the Mg/ $\alpha$ , n/Si process with the use of a Boron trichloride neutron counter, and studied the Al excitation equation through  $\alpha$  ray bombardment. Laszlo Medveczky investigated the Mg/ $\alpha$ , n/P process by a photoemission method and noted the energy distribution of the neutrons of the Al/ $\alpha$ , n/P nuclear process. S. Szalay and Tibor Fenyves constructed a new type electron-magnetic  $\alpha$ -ray spectrometer. S. Szalay gave a report on the excitation state of light atom nuclei at the First Hungarian Rotating Congress of Physics. L. Medveczky developed the photoemulsion method for the neutron spectroscopy. L. Medveczky and Erno Bujdosó are developing a dark-field microscope method for use in conjunction with the photoemulsion method for examination of

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neutrons. J. Kádveczky is utilizing a photo-emission method for determination of the energy spectrum of the Po - Be neutron source. Janos Nagy is investigating the  $B_5/\alpha$ ,  $n/N_7$  nuclear transformation.

#### (b) Petrographic Radiological Investigations

In 1946 S. Szalay initiated the prospecting for sizeable deposits of uranium in Hungary. This problem is very important from the point of view of the peaceful uses of atomic energy. When traces of uranium were discovered in the Transdanubian coal fields this research had a great effect on the national economy. A discovery of considerable theoretical importance was the discovery by Szalay and his associates of the cause of the geochemical concentration of uranium in organic substances. From this it is hoped that a cheap method for the extraction of the uranium may be developed, and that this low concentration occurrence of uranium may meet the power demands of Hungary for several centuries. It is an important task, therefore, that in the field the uranium prospecting be continued and that the uranium content of the domestic coal fields be mapped, and in the laboratory that the uranium-concentration and metallurgical experiments be furthered. Many scientists participated in this extremely varied research, the results of which have appeared in more than 20 publications, including 7 by Sandor Szalay, one by Szalay-Csongor, 5 by Szalay-Foldvari, 2 by A. Foldvari, 4 by B. Makranczi, 3 by Almassy-Nagy, one by Almassy-Straub, one by Almassy-Kovacs, 3 by Almassy and one by Almassy-Dezso.

#### (c) The Use of Radio-Isotope Tracers

The use of radioactive isotopes in the fields of medicine and biology was begun during the past decade with the application of naturally radioactive-, and bizmuth isotopes. The necessary equipment for use in this field was developed by the institute headed by S. Szalay, and a doctor (Laszlo Kertesz) and several laboratory assistants were specially trained for research requiring medical attention. One of the important scientific achievements in this field has been the development of quantitative histochemical procedures through the use of radioactive isotopes (in conjunction with the institute headed by Imre Toro). Another important achievement has been the investigation of the functioning of defense mechanism which protects the living organism from particles which intrude into it through the use of colloidal particles marked with radioactive isotopes.

Experiments may be conducted on an adequate scale only after the remodeling and installation work at the Debrecen Physics Research Institute are completed. The researchers who have done work in this field and have published accounts of their work are the following: Szalay-Barka-Posalaki-Kertesz, Barka-Kertesz-Gerecse, Szalay-Posalaky, Bartos-Kertesz, Szalay-Kertesz-Simonyi, Kertesz-Aros-Barka-Posalaky, Keztyus-Valyi Nagy-Kertesz-Kocsar, Barka-Posalaky-Kertesz, Aros-Barka-Posalaky-Gerecse, Kocsar-Salaky-Kertesz-Szalay-Keztyus, Kocsar-Keztyus-Szalay-Kertesz-Valyi Nagy, Valyi Nagy-Kocsar-Kelentei-Keztyus-Czernyanszky-Kertesz-Okros, Szalay-Kertesz, Keztyus-Szalay-Kocsar-Kertesz-Salanky, Barka-Posalaky, and Kertesz-Toro-Szalay.

To this list of names it must be added that this field of research reflects the collective efforts of scientists because the medical application of radioactive isotopes requires the joint work of many specialists. This is significant also for individual modern scientific research and achievement.

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A 280,000 v small neutron generator is being built at the Debrecen institute. The neutrons generated by this machine will in turn produce new artificially radioactive isotopes. Another machine [also under construction at the Debrecen institute] is a 2,000,000 v Van de Graff generator, which will accelerate ions for the purpose of transformation of atom nuclei. A report by Szalay-Puskas deals with the latter.

In other fields of research, regular measurements have been made at the Institute since 1952 for the determination of the radioactive content of the atmosphere. The latter shows great variation due to remote explosions of atomic bombs. Investigations by Szalay-Berenyi and Decsi-Horvath on the increase in radioactive pollution (radium emanation) caused by spilling of krypton at the Krypton Plant were aimed at the protection of the health of the plant workers. From a practical viewpoint it is important that the planned Debrecen Physics Research Institute of the MTA be completed to a point where it would be equal to the development of the allied fields.

#### The Physics of Solid Bodies

The following institutions are active in this field: Experimental Physics Institute of the Technical University of the Construction Industry (academician Zoltan Gyulai and associates); Physics Institute of the Eotvos Lorand University; Physics Institute of the Szeged University; Physics Institute of the Budapest Medical School, and the Telecommunications Research Institute.

Zoltan Gyulai and his associates have done work on problems of the electrical conductivity of hard semiconductors and on crystal growth and recrystallization.

Gyulai and Tomka have shown that there is a variation in Ohm's law observable in colored alkali halogen crystals. Boros has investigated electrical and optical peculiarities of vanadium pentoxide crystals and has shown that the disturbing energy level may be reached by either electrical or optical means.

Boros and Sibelszky obtained the identical result with both colored and de-colored alkali haloids.

Boros and Csaszar demonstrated that the activation energies produced during conduction in NaCl and KBr tablets are the same as those determined by optical measurements. They explain this phenomenon by the fact that electrons participate in the conduction process.

Tomka investigated deviations from Ohm's law in the conductivity of colored, and de-colored alkali haloids. He also has concluded that a great role must be attributed to electrons in the process of electrical conduction.

Several of the works of Gyulai were devoted to the problems of crystal growth. Gyulai established the fact that in growing a crystal from a solution a very important role is played by the transitional layer between the solid phase and the solution, and he cites several examples.

Gyulai, together with Imre Tarjan and Gyula Zimonyi have developed a method for the synthetic production of quartz crystals. He has developed several methods for growing needle-crystals of NaCl and he has investigated the elastic and rigid properties of these crystals. In this investigation he reached the noteworthy conclusion that the structure of the needle crystal is much more perfect than that of the large single



crystals. In further work on growing needle crystals he discovered that needle crystals have a destructive effect in porous substances. (Z. Gyulai was awarded the Kossuth Prize in 1953.)

Gyulai and Morlin are performing a series of experiments involving NaCl tablets. They find a correlation between pressure, temperature and particle size. They have established that in recrystallization in the solid phase the crystal growth follows the Kossel pattern, just as in crystal growth from solution or from vapor. Gyulai and Morlin connect their recrystallization investigations with the dislocation theory of solid bodies.

Gyulai, working with Szilvassy and Gaal, discovered that a thermo-electric potential may arise also between the oxides of semiconductors.

Tarjan and his associates at the Budapest Medical Physics Institute are doing work on the color centers which cause the coloration of alkali haloid crystals. They have studied the absorption and the light-electrical properties of crystals which have been treated with x-rays, and crystals which have received additive coloring. They developed methods for the production of various single crystals, such as single phosphorus alkali haloid crystals for scintillation counting equipment for use in atomic physics. They also have produced single crystals of naphthalene and anthracene for similar purposes.

Most of the work of Pal Selenyi has been in the field of semiconductors. Selenyi was the Hungarian expert who worked out the technology of the manufacture of selenium rectifiers in Hungary, and he contributed a further theory on the functioning of selenium rectifiers. Selenyi had performed numerous investigations on the semiconductor selenium, during the course of which he has shown that selenium can be used for a photographic plate. He discovered that when a selenium rectifier plate is bent the closing current increases, and the increase subsides after a period of time. He made selenium photoelectric cells sensitive to ultrared light by exposing the photoelectric cell to mercury vapor.

Pal Selenyi died one year ago. In his decease Hungary lost a first-rank researcher and an inspired teacher. The Kossuth Prize which he was awarded in 1951 was only an indication of the esteem of the country, and could not make amends for the suffering which he had to endure. It is essential that he be remembered with esteem in the present report.

At the Experimental Physics Institute of the Szeged University investigations are being conducted on semiconductors and on luminescence. Gombay has investigated lead sulfide and lead selenide, and Gombay and Lang have investigated ferrosilicon. The other field of research of the Institute concerns the luminescence phenomena of organic plant phosphors. These investigations were conducted by Frohlich and his students: Gombay, Szalay, Szor, Dombi, and Ketskemety. The light absorption and emission of gelatin phosphorous paints were investigated by Frohlich and Szor. Frohlich and Szalay investigated the effect of a rotating magnetic field on a luminescent plate. They attempted to explain the phenomenon of preexcitation through the light absorption by oriented molecules. Gombay showed that a photoelectric current appears in these phosphorus paints. He considers this to be the same as the current which appears in inorganic types of phosphorus. He theorizes that the conductivity of the gelatin plates is a type of organic conductivity. The thermal potential which he measured on these preparations is another proof that electrical conductivity exists under these conditions.

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Szalay is working on the excitation and preexcitation of organic phosphorus compounds, and on the saturation of emission. He shows that the gelatin phosphorus plates rotate the plane of light polarization. Szalay and Szollosy are jointly developing a method for the demonstration of self-excitation. Szalay and Grasselly have investigated the structure of gelatin, and have come to the conclusion that gelatin must have a crystalline structure. Szor has been doing work on the absorption of an NO alcohol solution of acridin orange. Dembi has been working on the permanent photodichroism of solid paint solutions. The theme of a dissertation by Ketskemeti was the luminescence of aluminum-morin.

The phenomena of luminescence of solid bodies, which has considerable technological importance, is under investigation at the laboratories of the Unified Incandescent Lamp Plant and the Electricity Company, which is now the Telecommunications Research Institute. Szigeti and Nagy investigated the emission of willemite. The emitted light was analyzed by means of a spectroscope. Gergely devised a method for the measurement of extinguishing time. This was no mean task, because the extinguishing times are in the order of one-millionth of a second. He and Valko use an electronic compensation method for measurement of the extinguishing time. Nagy and Gergely show that the various emission bands have different extinguishing times. Makai successfully explained the 2 emission bands of willemite. The lighting capacity decreases with the temperature. According to Szigeti there is a connection between the decrease in lighting capacity and the constant dielectrical increase. Nagy, and later Bodo, investigated the role of the activator and of pollution in luminescence. It is very important from the point of view of understanding the mechanism of excitation that the absorption coefficient of these substances be known within the ultraviolet range. This is not an easy task when it is remembered that these substances are in a powdery form. Several of the works of Bodo were devoted to this subject, and he succeeded in determining the absorption coefficient of the powdery substances. Bodo also determined the absolute efficiency of light transformation of these powdery substances. On the basis of their results Nagy and Bodo established a hypothesis for the laws governing the lighting capacity, which was useful in the explanation of many other phenomena. The investigations of Nagy pertaining to the centers offer great possibilities for evaluation of other luminescent phenomena which are studied in relation to these centers. During the past 2 years the work at the laboratory has included, in addition to research on luminescence, the production of transistors, and investigation of the electroluminescence of silicon carbide (SiC).

#### Analysis of the Structure of Substances Using X-Rays

The work in this field during the past 10 years has been done by Naray-Szabo, Sasvari, Szanto, Papp, and Hegedus. Naray-Szabo have been working on the class of crystals exhibiting perovskite structure. Papp and Sasvari have employed the electron multiplier for the measurement of x-ray intensity in determining crystal structure. Sasvari has determined the structure of bayerite, and has investigated the origin of alpha-corundum rocks. Sasvari and Hegedus have been tracing the thermal origin of aluminosilicate hydrates by x-ray and thermoanalytical methods. Szanto has developed a method for measurement of the internal strain of metals, using x-ray diffraction, and he established an accurate grid parameter, using alpha-titanium. Sasvari developed a method for measurement of the elastic tension of metal wire, using a back-reflecting x-ray chamber.



### Acoustics. Supersonic Waves

In the field of acoustics and supersonic waves, the following researchers may be mentioned: Tarnoczy, Greguss, Tari, and Szilard. In many of his works Tarnoczy has made sound disc recordings, and he has studied the acoustics of the Varosi Szinhaz (Municipal Theater) (which is now the Erkel Theater of the State Opera). He drew up plans for the correction of the poor acoustics of this theater, and on the basis of these plans the acoustics of the theater have been improved. His use of acoustically diffuse surfaces for the improvement of acoustics is the first such example in the literature. He also has developed a balance for the measurement of supersonic wave pressure. Together with Greguss he developed a method for the precipitation of aerosols (cement dust), using supersonic waves. In a joint work with Somhegyi he shows that acoustic energy influences the processes of combustion. In a joint work with Tari he used a condenser microphone for measurement of the amplitude of acoustical vibrations. Greguss established the fact that supersonic waves cause a change in coloration of certain colored solutions, which may be used for measurement of supersonic wave intensity. Szilard developed a method for the measurement of supersonic wave intensity, using the so-called compensating calorimeter.

This brief account cannot give a detailed picture of the entire theoretical experimental work which has been carried on in Hungary. An indication of the scope of the work which has been done is the fact that the individual publications, which do give a detailed account of research in physics in Hungary during the past 10 years, total approximately 400 volumes, with more than 2,000 pages.

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